PATTERNS OF INSULAR SHARK DYNAMICS BASED ON FISHERY BYCATCH AND LIFEGUARD SURVEILLANCE AT OAHU, HAWAII 1983–1992

Frank A. Parrish and Ralph S. Goto

ABSTRACT

Incidental shark sightings recorded by beach lifeguards and records of shark bycatch from fishery catch reports were evaluated as possible long-term indices (1983-1992) of insular shark dynamics. The daily lifeguarding of the 17 Oahu beaches provided a documentation of effort not available from fishery data. Identified seasonal and spatial trends in shark sightings were found to persist through successive years of surveillance and were roughly consistent with distributions of fishery bycatch. However, it was possible to attribute shark bycatch to changes in accessibility of fishing grounds and size of the fishing fleet. An evaluation of the potential biases in lifeguard data indicated that variables such as wind/surf conditions and beach attendance did not govern the frequency with which sharks were reported. Summer increases in sightings coincided with shark pupping activities, and winter pulses were roughly associated with periods of increased rainfall. Relationships with coast and season were evident, with significantly more sightings on the island's leeward coast. A survey of shark-related news stories compared with reports of shark sightings suggested that shark sightings increased on a limited scale with high media exposure. No consistent trend in abundance of sharks was detected over the full 10-yr period. The interannual pattern of shark sightings (scaled for effort) remains unexplained, despite comparison with fishery data, island runoff, sea-surface temperature, and known El Niño events.

Long-term movements of sharks in coastal regions are of interest worldwide because of human-shark interactions, increasing directed shark fisheries, and increasing shark bycatch (Russell, 1993: Bonfil, 1994). In Hawaii, awareness of some of these issues has heightened due to recent shark attacks (Borg, 1993) and high shark bycatch documented in segments of the fishery (Dollar, 1994). Use of available data from commercial landings to assess temporal and spatial movements of sharks is often complicated by poorly known or undocumented fishing effort. Commercial fishermen in Hawaii are required to submit a monthly catch report including date, area, type of gear, taxon, and weight caught. (Using this information, it is possible to estimate the number of fishing trips made.) Not included is information as to the amount of gear used or its frequency/duration of deployment—precluding any rigorous calculations of effort. Some approximation of effort can be made for some individual target species by focusing on their particular gear types, but in this fishery sharks occur as bycatch of nearly all gear types. Consequently sharks are often unreported, and those that are reported are coded simply as "shark."

An unconventional alternative to using fishery data might be the analysis of incidental shark sightings recorded by beach lifeguards. Typically, these data have been overlooked or dismissed because of the perceived subjective nature of shark sightings and "free" format often used for recording. Although information such as shark species and size is likely to be haphazard and unconfirmed, the context in which the sharks are sighted can involve a highly systematic and rigorously documented effort. Analysis of such shark sightings, with recorded information such as location, date, observational effort, and en-
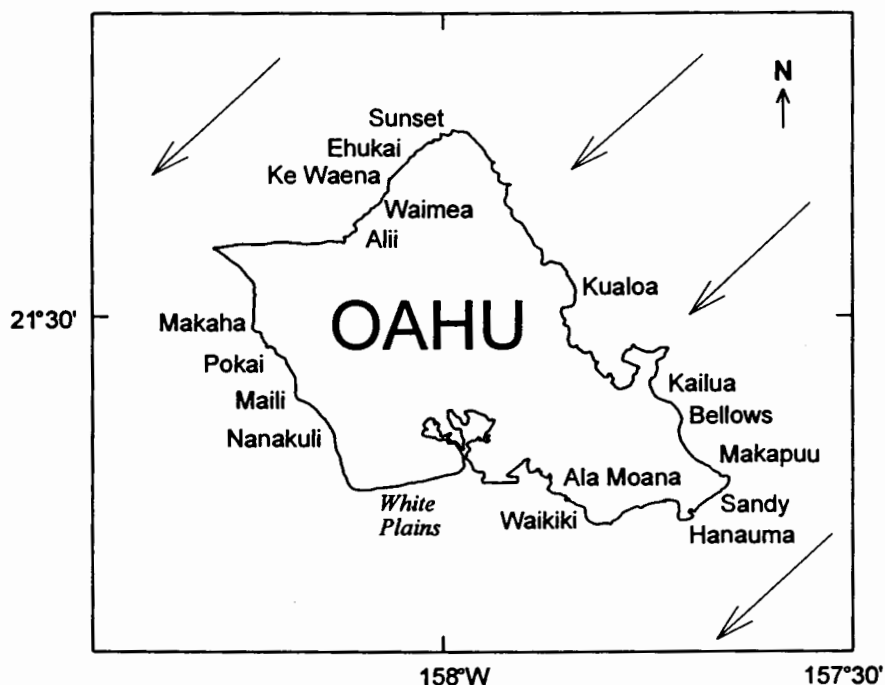
Figure 1. Location of beaches guarded by Oahu's Water Safety Division. The independently guarded "White Plains" beach is included in italics. Arrows represent prevailing direction of trade winds and surface currents.

vironmental conditions, could provide useful insights. The present study examines some data from lifeguards and fishery bycatch from Oahu, Hawaii to evaluate shark sightings as an index of spatial and temporal trends in relation to the island environment.

The lifeguard data were collected by the City and County of Honolulu's Water Safety Division, which guards 17 Oahu beaches, 15 of them on a daily basis. The beaches occur on all sides of Oahu and vary in exposure to prevailing wind and sea conditions (Fig. 1). Ranging between 1 and 3.5 km in length, the beaches are guarded between 08:00 and 17:00 h. The lifeguards occupy 3-m high towers overlooking the water and are equipped for surveillance (e.g., sunglasses, binoculars, diving mask). The number of lifeguards on a given beach varies with its average attendance and size. A "Water Safety Officer Station Log" is used daily to record the estimated number of beachgoers, wind speed, and surf height at designated time intervals throughout the day. The log includes a "station activities" section organized by hour with space for lifeguard comments. Lifeguards routinely assess, act on, and record incidents of potential hazards to beachgoers' safety, including shark sightings. Shark sightings reported to lifeguards by beachgoers are included on the log, and usually lifeguards attempt to personally verify such sightings. Based on a shark's size or its proximity to the beach, the lifeguards issue warnings, post signs, or clear the water.

METHODS

FISHERY BYCATCH DATA. — Commercial catch reports for 1983-1992 inclusive were searched for all records of shark bycatch within the State's reporting areas concentric with the Oahu coast (from shore out to 37 km). The number of records in relation to the size of catch was examined, and extreme outliers in the distribution were excluded from subsequent analysis. As no effort was documented, validity of distributions resulting from these data is unknown. Available history of Hawaii's fleet size and movements (Anonymous, 1994a) was used to critique trends in bycatch data (Pooley, 1993).

LIFEGUARD SIGHTINGS DATA. — Station logs were searched for shark sightings during the 10-yr period from 1983 to 1992 inclusive. The number of shark sightings was compared to the number of lifeguards per beach to determine whether beaches with multiple guards recorded more sightings. The effect of beach attendance on shark surveillance was tested by comparing the number of beachgoers on the days sharks were sighted to the number on days they were not. Effects of variable wind and surf on visibility and the subsequent frequency of sightings were assessed. The relative exposures to prevailing wind and surf for the various beaches were compared to determine whether these coastal variables, which can affect visibility, influenced the incidence of sightings.

COMPARISONS BY SEASON AND COAST. — No sizes for sharks are available from fishery bycatch. Shark size data recorded by lifeguards were examined and assessed for size specific trends. Sightings and bycatch were then grouped by month to assess seasonal variability. Monthly cumulative rainfall data (National Climate Data Center, NOAA) and mean sea-surface temperature data (Honolulu, NMFS, unpubl. data) were compared with the seasonal distribution of sightings.

Sightings and bycatch were then grouped by coastline (facing north, south, east, or west) to examine spatial differences. The frequencies of sightings and bycatch by coastline were cross-classified by season. Trends of bycatch by coast were compared with documented usage of ports (Hamm and Lum, 1992) on the various coasts by fishing vessels.

INTERANNUAL COMPARISONS. — Bycatch and beach sightings were grouped by year. Significant changes in the size and regulation of the commercial fleet over the 10-yr period were considered in relation to the bycatch data (Boggs and Ito, 1993). The two sources of shark sightings; i.e, lifeguards and beachgoers, were tested for annual agreement pooled over all beaches.

Possible annual variations in shark sightings due to shark-related media reports (Protess and McCombs, 1991) and environmental variables were tested. As an index of media intensity, the island's primary newspapers (*The Honolulu Advertiser* and the *Honolulu Star-Bulletin*) were searched for every news article concerning sharks that was released during the 10-yr period. The circulation of the two papers included between 65 and 75% of Oahu's adult residents during the study period (the highest percent distribution in the U.S.A; pers. comm., Hawaii Newspaper Agency). The frequency and dates of shark-related newspaper articles were then compared with the dates sharks were sighted for relative proximity in time. Interannual shark sightings were also compared with an index of annual Oahu stream discharge (Hawaii gauge stations 16200000, 21160000, 16226000, 16229000, 16302000 and 16303000; USGS Water Resource Data-Hawaii and other Pacific areas, Vol. 84-93). Finally, because Hawaii's coastal waters abruptly meet the pelagic environment, annual sightings were compared with sea-surface temperature (Honolulu, NMFS, unpubl. data.) and known El Niño Southern Oscillation events (ENSO)(El Niño Monitoring center, Japan Meteorological Agency 1996).

STATISTICAL ANALYSES. — The small sample sizes and categorical nature of the data used in the analysis of this work required methods such as standard nonparametric regression, correlation, one- and two-way comparisons, contingency, and goodness-of-fit tests (Siegel and Castellan, 1988; Birkes and Dodge, 1993).
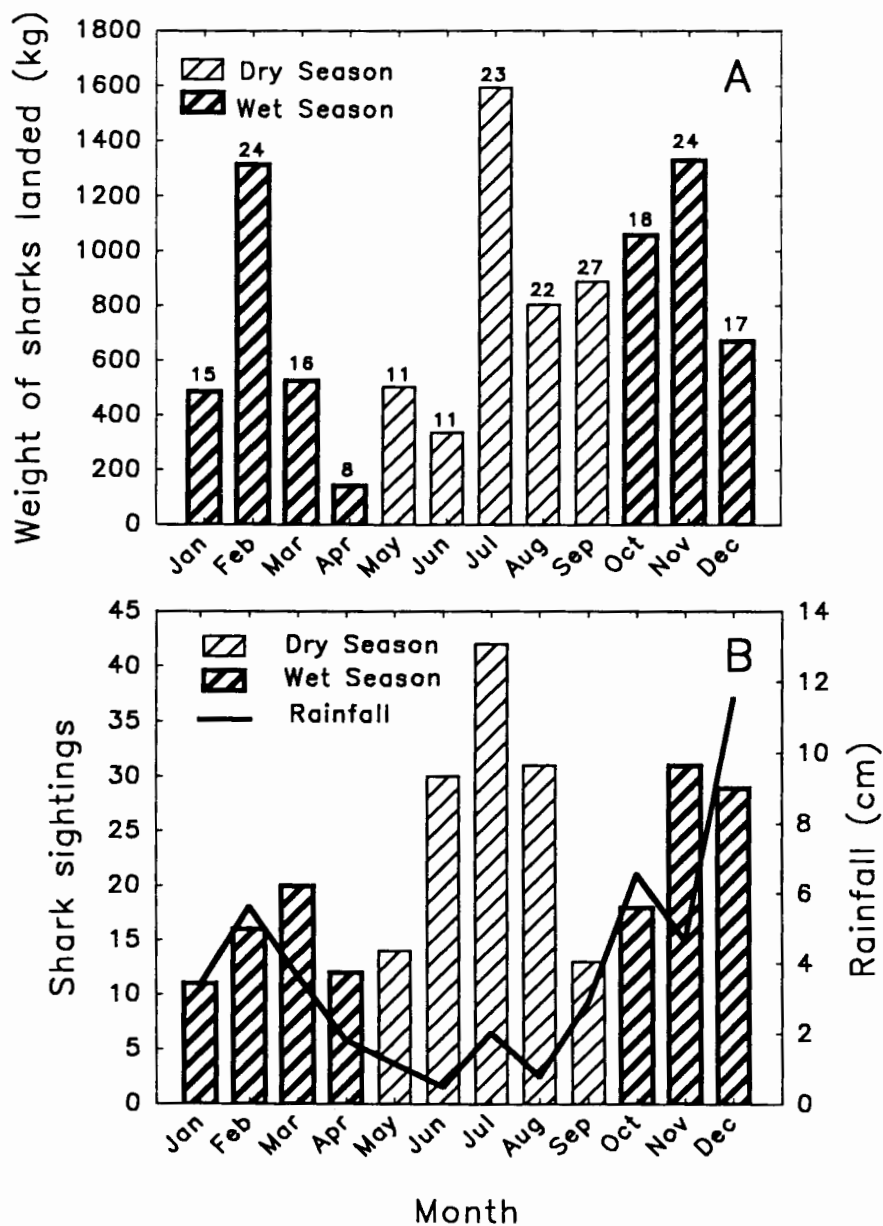
Figure 2. Monthly reports of (A) shark bycatch and (B) shark sightings (standard effort), for the 10-yr period, with dry and wet seasons indicated. The number records are listed on top of each monthly column in (A). Median rainfall is represented on (B) by the imposed solid dark line read on the right ordinate.
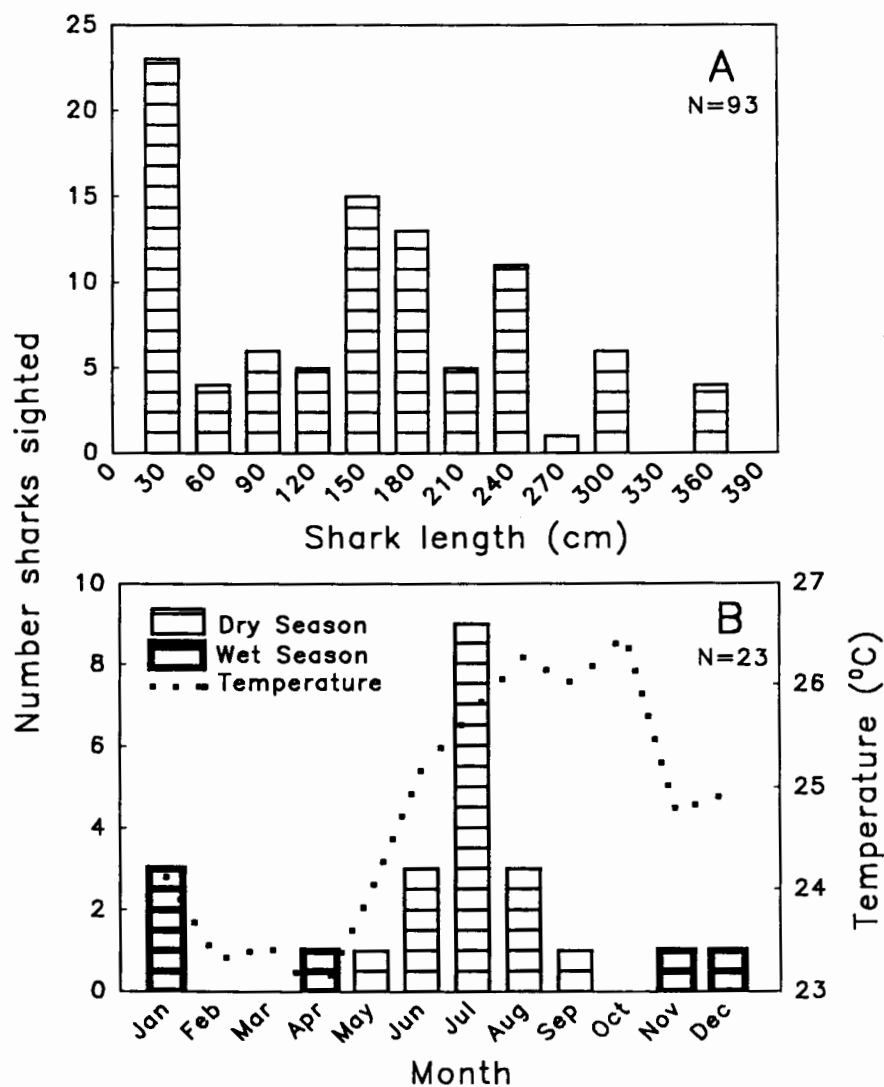
Figure 3. (A) Distribution of estimated lengths of sharks sighted; an abundance of shark pups is indicated. (B) Temporal distribution of sightings of the 30-cm sharks from graph (A); the majority are part of the summer pupping season. Sea-surface temperature data (dotted line) are provided (scaled on the right ordinate).

RESULTS

SAMPLE SIZE AND BIAS. — The catch reports yielded 284,000 fishery records from Oahu waters over the 10-yr period. Of these, only 213 records of shark bycatch were reported, providing a total of 9134 kg of shark. The weight of shark catch per record ranged between 1 and 268 kg. The records indicate that the sharks were caught using 12 different gear types. Combining roughly equivalent gear types, 87% percent of the records were split between handlining (42%), trolling (33%) and longline fishing (12%). Each of
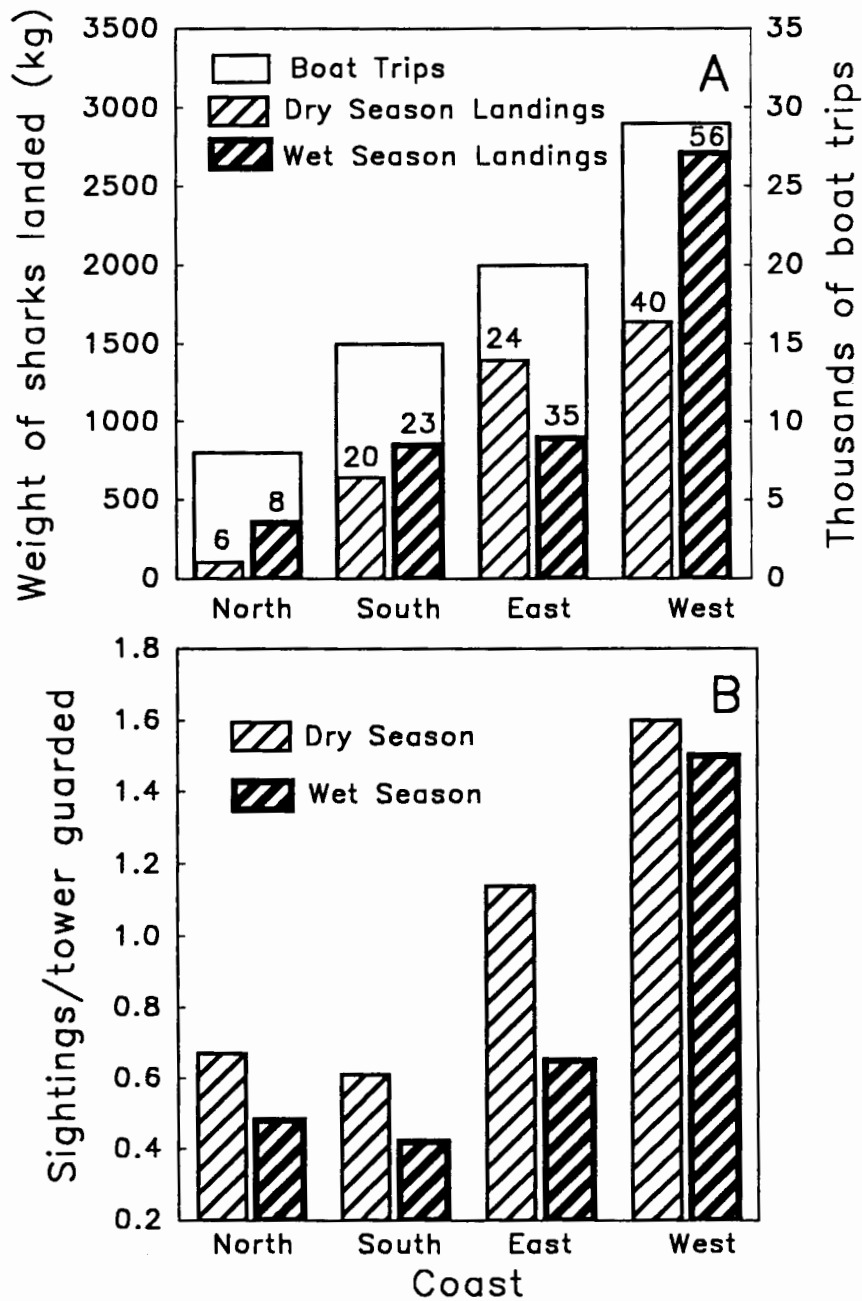
Figure 4. (A) shark bycatch and (B) sharks sighted/tower guarded, by coastline, during dry and wet seasons (data normalized for the unequal lengths of the two seasons). Bycatch data (A) includes data on Oahu's relative usage of coastal ports and the number of bycatch records each kg column reflects.

Table 1. Oahu beaches with lifeguards of the Water Safety Division, City and County of Honolulu. Data include the number of towers guarded (number of guards) at each beach over the 10-yr surveillance, the mean annual number of sharks sighted per towers guarded, median shark length, and the total number of sightings with length estimates (sample size). Also included are the same data for White Plains Beach, administered by Barbers Point Naval Air Facility.

| | | | | Shark length | |
| | | | Annual shark | | |
Coast	Beach	Number of guards	sightings per tower guarded	Median (cm)	Sample size
North	Alii	1	1.1	30	2
	Ehukai	1	0.30		0
	Ke Weana	1	0.40	150	2
	Sunset	1	0.60	150	1
	Waimea	1	0.40	30	1
South	Ala Moana	5-6	0.27	143	10
	Waikiki	7	0.68	135	23
East	Bellows	1	0.71	210	2
	Hanauma	2	1.05	30	9
	Kailua	1-2	1.10	180	12
	Kualoa*	0-2	0.47		0
	Makapuu	1	0.40	90	1
	Sandy	1-3	0.57	165	2
West	Maili	2	1.15	195	6
	Makaha	2	1.35	180	4
	Nanakuli	2-3	2.79	180	11
	Pokai	1-2	1.11	45	6
South west	White Plains**	1	5.14	180	5

*Kualoa was not guarded during 1983-86.
**Data based on incomplete records between January 1988 and July 1992.

these gear types targets pelagic species in the nearshore island waters except longline fishing, which in the 1990's moved increasingly to the open sea. For complete descriptions of fishing gear and changes in the fishery see Pooley (1993) and Boggs and Ito (1993). Other than estimates of the number of boat trips, no fishing effort is available for these data.

The search of 117,000 lifeguard station logs yielded 267 reports of one or more shark sightings. Sharks were sighted at all beaches. Twenty of the sightings specified the presence of multiple sharks ranging from 2 to 15. Twenty-one were reports of dead sharks found or landed on the beach. Size information was included for 93 sightings, and estimates ranged from 30 to 400 cm in length. Shark identification was attempted for 47 sightings; the types recorded were hammerhead, reef, grey reef, blacktip, whitetip, tiger, and mako sharks. Except for reports of hammerheads, little credence was given to specific identifications, but the steepness of the insular slope makes sighting of both nearshore and oceanic sharks plausible. Sharks were reported as close as the water's edge and as far as 300 m offshore.

Lifeguard effort varied among years and among beaches but did not vary within year at a given beach. Total annual lifeguard surveillance effort for all Oahu ranged roughly between 11,000 and 12,500 guard-days. Lifeguards observed 59% of the total sharks
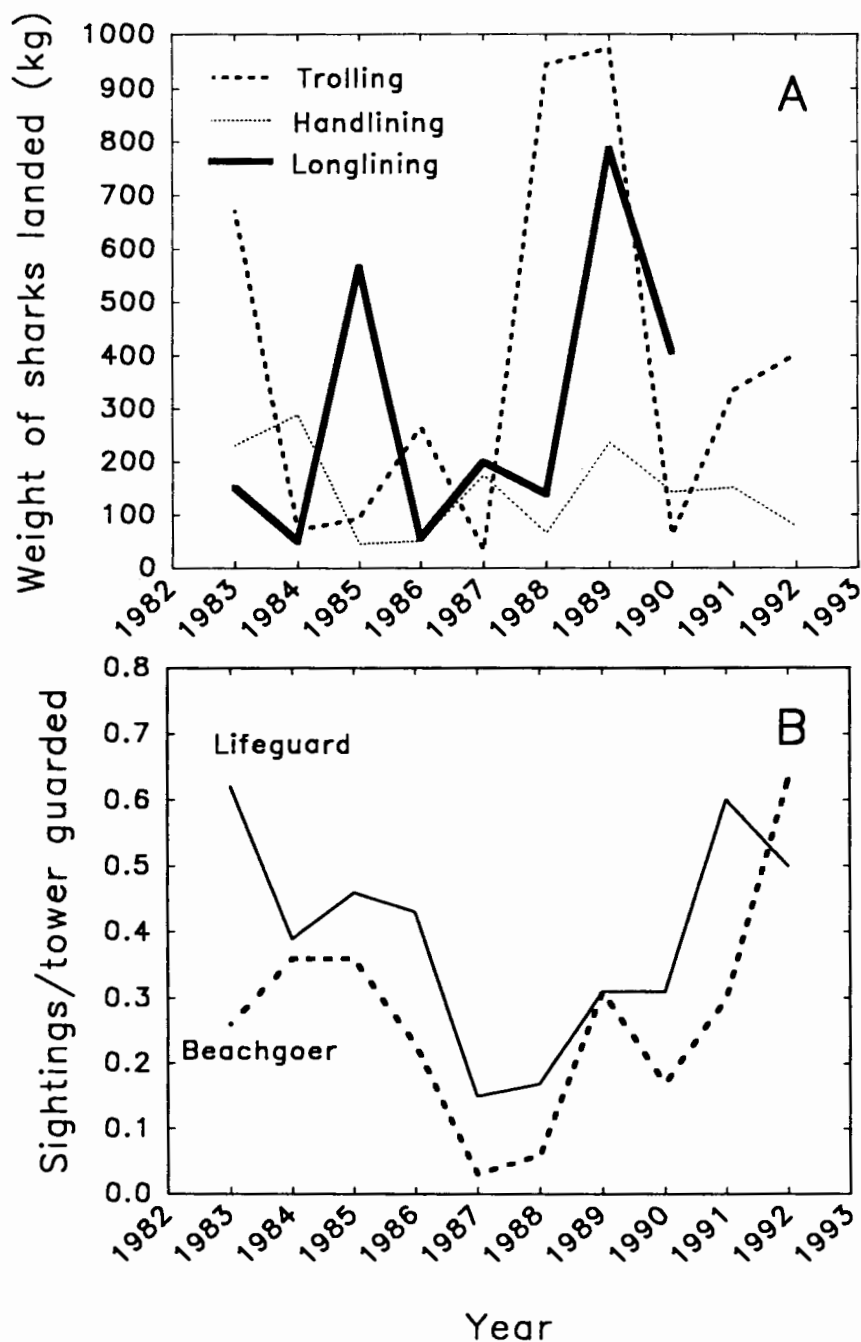
Figure 5. (A) Annual shark bycatch from Oahu waters for the three gears which produced 87% of the bycatch: trolling, handlining, and longlining. (B) Annualized number of shark sightings/tower guarded as reported by lifeguards and beachgoers. Reports by beachgoers exceed those of lifeguards only in 1992.
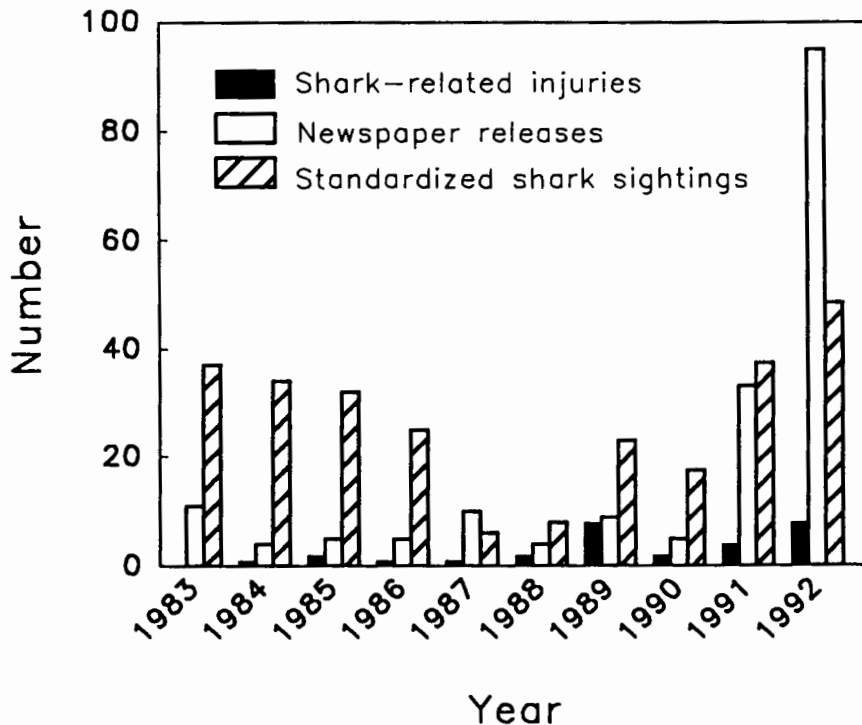
Figure 6. Numbers of documented shark-related injuries, shark-related newspaper articles, and standardized shark sightings from lifeguard surveillance, by year for the years 1983-1992, inclusive.

reported. At beaches staffed with multiple guards, more than one guard observed 38% of the sharks reported. (Replicate sightings were excluded in arriving at the total 267 reports.) The presence of multiple guards influenced the frequency of sightings for a given beach (Rank-based regression (RBR), $r^2 = 0.35$, $P < 0.01$), encouraging standardization for number of towers guarded. Estimates of total annual attendance at all guarded beaches combined varied between 12.5 and 29.4 million people (Water Safety Division, Statistical Activities Reports 1983-1992). Significantly more shark sightings occurred on days of below average beach attendance (Wilcoxon paired sign ranks (WPSR), $Z = -3.47$, $P < 0.001$); therefore, more beachgoers did not result in more shark sightings.

Frequency of sightings decreased continuously with increasing surf height (Spearman's Rank Order Correlation (SPROC), $r_s = -0.86$, $P < 0.01$) but not with increasing wind speed (SPROC, $r_s = -0.57$, $P = 0.31$). Most of the sightings occurred at wind speeds typical of the island trade winds, and sightings were not especially frequent on the calmest days. The prevailing trade winds can produce a variety of local wind and surf conditions at different beaches depending on their windward or leeward orientation. The analysis that included individual beaches indicated that shark sightings were independent of surf height and of the beaches' relative exposure to wind (wind:RBR, $r^2 = 0.02$, $P = 0.56$; surf:RBR, $r^2 = 0.10$, $P = 0.19$).

TRENDS WITH SEASON AND COAST ORIENTATION. — Roughly consistent summer and winter pulses were apparent in the seasonal distributions of both the lifeguard sightings and

fishery bycatch (Fig. 2). The summer pulse was generally coincident with shark pupping activities. Lifeguards documented a large proportion of pup-size sharks distinct from the size distribution of older sharks (Fig. 3A). Nearly all the pups were identified as hammerheads and observed primarily during the dry season (Chi square test, $x^2 = 4.96$, P < 0.05)(Fig. 3B). Available information on the seasonality, pup growth, and residence time of Hawaii hammerhead sharks (Clarke, 1971; Wass, 1971) was consistent with the observed distribution of sightings reported by lifeguards. If summer sightings consist mostly of pups and adults engaged in pupping/mating activities, the adult shark sightings during the remainder of the year (September-May) roughly follow rainfall of the island's wet season (SPROC, $r_s = 0.57$, P = 0.090)(Fig. 2B).

The trends in shark bycatch and shark sightings by coast were surprisingly similar. However, port usage on Oahu by coast for fishing vessels in a large segment of the fishery (Hamm and Lum, 1992) (excludes large vessels such as longliners) suggests that trends in the bycatch data could be an artifact of coastal access (Fig. 4A). No similar artifact is obvious for the lifeguard data. Significantly more shark sightings occurred on west Oahu - nearly twice the number recorded for east Oahu, the second ranked coast (Fig. 4B). The four west Oahu beaches had the island's four highest sighting rates (Table 1). Significantly fewer sightings were reported from the north and south shores. Sightings were considerably more frequent during the dry season on three of the coasts and slightly more frequent at west Oahu. In contrast, bycatch was highest in the wet season. Month and coast had significant effects on the distribution of sightings (Friedman 2-way ANOVA, $x^2 = 158.9$, n = 267, P < 0.001).

ANNUAL VARIABILITY.— The sporadic distribution of yearly shark bycatch was difficult to evaluate. An observed peak in 1988 and 1989 (Fig. 5A) might have resulted from the expansion of Hawaii's fishing fleet (Pooley, 1993). Estimated fishing trips for three primary gears indicate that trolling increased throughout the 10 yrs, handlining remained constant, and longlining abruptly increased beginning in 1988 (Anonymous 1994b). For each gear type, fishing was unrestricted near shore until 1990, when longlining was restricted to ≥80 km offshore by regulation (Boggs and Ito, 1993). Otherwise, the distribution of the landings and their poor concordance suggests that the size of Oahu's annual bycatch has little to do with annual changes in the shark population.

No overall increase or decrease was seen in shark sightings during the 10-yr survey period (Kolmogorov-Smirnov (KS), D = 0.536, P = 0.93). The most distinctive feature of the annual distribution of shark sightings was a depression in sightings during 1987-1988. The agreement between annualized sightings by lifeguards and those reported by beachgoers (Kendal's coefficient of concordance (KCC), W = 5.44 P < 0.05) strongly suggests that observations by both groups reflect real interannual variation in occurrence of sharks. Beachgoers sighted more sharks than lifeguards only in 1992 when they accounted for 58% of that year's sightings (Fig. 5B).

The Honolulu Advertiser and the *Honolulu Star-Bulletin* printed 181 shark-related articles within the 10-yr period. Seventy of these reported a specific incident involving a shark; the remaining 111 were follow-up and general articles about sharks and previous incidents. All were used in the media analysis. The only significant change (Kruskal Wallis (KW), $x^2 = 25.22$, P < 0.01) in the annual number of newspaper releases was the increase of 1992 (Multiple comparisons test, Z = 3.3, P < 0.01)(Fig. 6). Figure 6 includes the annual numbers of documented incidents of shark-related injuries chronicled by the media. (Includes fatal cases in which it is uncertain if death resulted from other causes
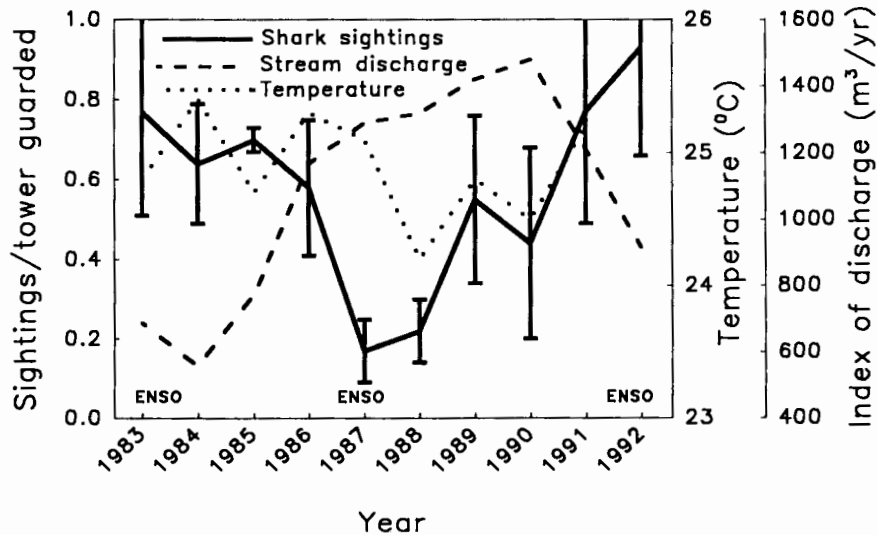
Figure 7. Annual stream discharge index (dashed line) and sea-surface temperature values (dotted line) plotted with annualized shark sightings/towers guarded (solid with SE's indicated). Recognized ENSO events are flagged.

[Balazs, 1993].)   The dates of shark sightings were found more closely related to the dates of previous media releases (WPSR, $Z = -1.98$, $P = 0.048$) than media releases following reported sightings.

Interannual sightings appeared to be independent of the expansion of the fishery in 1987-1992 and of several conspicuous variables of the island environment (Fig. 7). Years of increased stream discharge did not result in more sightings; instead, sightings were nearly inversely related (SPROC, $r_s = -0.60$ $P = 0.066$). Mean annual sea-surface temperature also failed to provide an explanation (SPROC, $r_s = -0.26$ $P = 0.39$). The major identified depression in sightings occurred during the 1986-1987 ENSO event; however, a similar major depression was lacking during the ENSO events of 1983 and 1992.

DISCUSSION

DATA AND POSSIBLE BIASES. — Despite the limited data available for shark sightings and shark bycatch, the distributions by season and coast for the two data sets were roughly consistent. No doubt underreporting occurred in both data sets, but it was particularly likely for shark bycatch. Furthermore, the species of shark bycatch even close to Oahu may be unrelated to those seen at the shoreline. It is hard to know whether bycatch trends are indeed linked to trends of lifeguard observations or are simply coincidental in nature. The available information on port usage and fishing trips hint that trends in bycatch are due to changes in effort. Even if fishing effort were well documented, it is difficult to make even mild assumptions using data from such a variety of gears (Casey et al., 1988). The best use of bycatch data may be to endorse the general pattern of seasonal differences appearing in the sightings data; spatial and interannual comparisons using bycatch are

likely to be confounded. The uncertainties associated with bycatch highlight the incentive for evaluating lifeguard surveillance data and direct the primary focus to lifeguard data for the remainder of this work.

No obvious biases in the lifeguard surveillance were revealed. Redundant records of sightings from beaches with multiple guards and records of infant and dead sharks suggest some degree of conscientiousness in the lifeguard surveillance. The majority of sightings on days of less than average beach attendance may suggest the presence of a confounding effect, such as sharks avoiding high densities of people. Arguably, high densities of people increase the lifeguard surveillance burden, and perhaps the guards would be more likely to miss recording sharks. However, beachgoers report 40% of all sightings, so their greater numbers should mitigate this effect somewhat. Thus, some sighting reports might occur on high attendance days, but this analysis shows none. The possibility of resighting the same shark on different beaches or different days represents the primary weakness of these data. The occurrence of resightings would be difficult to detect and would tend to inflate the estimate of abundance. Even sharks resident on the insular slope have been shown to make extensive movements (McKibben and Nelson, 1986). Because of potential resightings, and because the number sighted is some unknown fraction of all sharks present, the shark sightings are treated as an index of relative abundance (Klimley et al., 1992).

SEASONAL AND COASTAL TRENDS. — The identified summer and winter pulses in shark sightings are consistent with seasonal shark movements identified in Hawaii and elsewhere. The association of the strong summer pulse with pupping activities was discrete and well represented in lifeguard sightings because the pups occur shallow and have small home ranges (Clarke, 1971; Wass, 1971). Reasons for winter pulses in sightings are less obvious, but the winter occurrence of sharks closer to coasts are well documented (Tester, 1969; Cliff and Dudley, 1992; Reid and Krogh, 1992; Krogh, 1994; Wetherbee et al., 1994). Although the association of winter sightings with rainfall was not significant at $P = 0.05$, it generally supported a hypothesis that sharks are attracted into shallower waters with increased seasonal runoff (further discussion below).

The number of sightings by coast, particularly the many sightings on the west coast, are different from results of research shark fishing done at Oahu in the late 1960's (Tester, 1969; Wass, 1971; Wetherbee et al., 1994). However, because lifeguard surveillance occurred from the beach, during daylight hours, and involved no active baiting, data from fishing and sightings may not be comparable. Similarly, the high commercial bycatch during the wet season versus the more numerous sightings during the dry season (Fig. 4) may reflect the inherent differences between what these two types of techniques can detect. Lifeguard data are perhaps best compared to data generated from prolonged antishark fishing along swimming beaches (Cliff and Dudely, 1992; Reid and Krogh, 1992). Both these methods sample close to the shoreline, generally involve no active baiting, and often pool shark species for analysis. Data from antishark fishing suggest that the configuration of the coastline can affect occurrence of sharks (e.g., a beach's relative proximity to deep water; Krogh, 1994).

The observed effects of coast and season on sightings may relate to influences of land on coastal waters. The prevailing westward oceanic drift (Bathen, 1978) is likely to maintain the highest degree of terrestrial influence in waters off the island's leeward coast. Gradients, of temperature, salinity, organics, and other materials carried by surface runoff, extending seaward from the southwest coast, may represent unique conspicuous fea-

tures in a relatively featureless oceanic environment. As a result, leeward beaches, particularly those close to point sources of terrestrial drainage, are likely to be "patrolled" more often by sharks (Pace, 1984; Coad and Papahn, 1988). This would explain the high incidence of sightings at west Oahu and the highest incidence at White Plains Beach, located at Oahu's southwest extreme, ~5 km downwind from Honolulu Harbor and Pearl Harbor (Table 1).

INTERANNUAL TRENDS. — Beachgoers reported more sightings than lifeguards only in 1992 when awareness of sharks rose. Late in 1991 and during 1992, several shark-related incidents occurred in Hawaii, including two fatal attacks on swimmers (Borg, 1993). As a result, news releases about sharks in 1992 were 10 times the mean of previous years. Shark sightings in 1992 were twice the average of previous years; sightings increased by 70% for beachgoers and by 30% for lifeguards. The effect of media reporting over the 10 yrs of shark sightings is less clear. The proximity of shark sightings to dates of previous news articles could suggest that shark-related media releases increase the likelihood of sightings on days following. But it is equally possible that newsworthy shark incidents occur as a result of variations in coastal shark dynamics. It is reasonable to assume that the extensive media coverage in 1992 enhanced 1992 shark sightings, particularly by beachgoers - a familiar phenomenon with shark attacks elsewhere (Burgess, pers. comm., 1995). However, the frequency of sightings in 1992 is roughly similar to sightings in 1983 when media releases were low. Overall, interannual variations in sighting frequency suggest that shark sightings relate to changes in frequency of shark occurrence more than to media exposure.

Previous studies have linked ocean temperature with changes in movements of oceanic sharks (Casey and Kohler, 1992) and have suggested that impacts from ENSO events might affect interannual patterns of shark sightings (Chirions-Vildoso, 1985). However, except for hammerhead sharks involved in mating/pupping activities, most sharks sighted from Oahu beaches are probably not oceanic species. Results of antishark netting done off Australian beaches (Reid and Krogh, 1992) suggested that temperature influenced seasonal changes in the frequency of some coastal sharks (*Carcharhinus* spp.), but no temperature information was available for interannual comparisons. In the present work, possible effects of temperature were detected in conjunction with higher sightings at leeward Oahu and seasonal pupping, but were not evident on an annual basis. The pooling of species in the lifeguard data may preclude identifying any specific interannual temperature effects. Conceivably, ENSO events might affect the annual pupping activities of hammerhead sharks; this could alter the annual distribution of sightings. However, no explanation is obvious for the lack of a consistent response to the three known ENSO events. Identified variability in the intensity of ENSO events has been linked to the occurrence and severity of drought in Hawaii (Schroeder, 1993). Interestingly, high sightings coincided with Hawaii's driest years - although no direct links with ocean species have been documented. The difficulty in quantifying the effects of ENSO events in Hawaiian waters perhaps confounds comparison with annual shark sightings.

The negative relationship between shark sightings and annual stream discharge is intriguing. Increased catches of sharks closer to shore during the wet season in Hawaii's coastal and pelagic fishing (Tester, 1969; Wetherbee et al., 1994; Polovina and Lau, 1994) prompted the inclusion of runoff as a variable in the present analysis. The observed negative relationship with runoff might occur because turbid runoff impaired the lifeguards' ability to see sharks. However, a notable percentage (30%) of lifeguard sightings

were documented in conditions of poor water clarity, indicating no severe impairment to sighting sharks. The episodic and highly dynamic nature of runoff into the deep waters around Hawaii may make associations between runoff and sightings hard to determine. Such dynamics would make interannual associations particularly difficult to detect. Any direct effects of runoff on sightings are likely to be brief, localized and sporadic, contributing primarily to spatial/seasonal patterns.

SUMMARY

Nearly all shark research involves secondary data sources such as landings of shark fisheries or shark bycatch from other fisheries. Lifeguard surveillance should be considered one of the possible sources, especially when considering coastal shark dynamics. In Hawaii, data from lifeguards and bycatch showed some similarities, but control against sampling bias was better in the lifeguard data. The spatial and temporal patterns in lifeguard data provide an empirical time series for Oahu on which to base hypotheses concerning insular shark dynamics. Use of conventional shark research techniques in conjunction with continued lifeguard surveillance may permit confirmation of the associations suggested by this preliminary analysis.

ACKNOWLEDGMENTS

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ADDRESSES: (F.A.P.) *Honolulu Laboratory, Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA, 2570 Dole Street, Honolulu, Hawaii 96822;* (R.S.G.) *Division of Water Safety, Department of Parks and Recreation, City and County of Honolulu, 3823 Leahi Avenue, Honolulu, Hawaii 96815.*